

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
11 December 2003 (11.12.2003)

PCT

(10) International Publication Number  
WO 03/102634 A2

(51) International Patent Classification<sup>7</sup>: G02B

(21) International Application Number: PCT/US03/17846

(22) International Filing Date: 4 June 2003 (04.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/386,084 4 June 2002 (04.06.2002) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,  
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,  
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,  
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,  
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,  
MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE,  
SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ,  
VC, VN, YU, ZA, ZM, ZW.

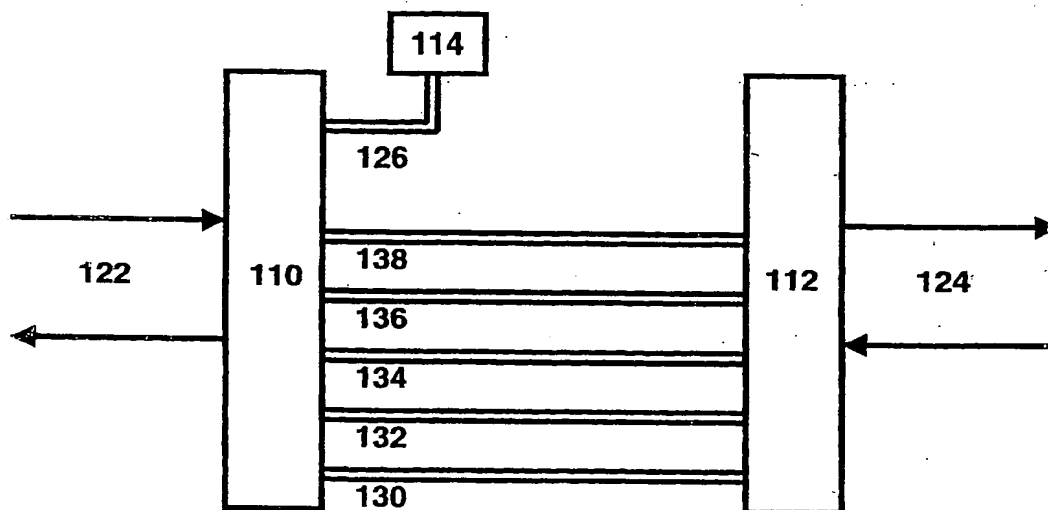
(84) Designated States (*regional*): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),  
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE,  
ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO,  
SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM,  
GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished  
upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guid-  
ance Notes on Codes and Abbreviations" appearing at the begin-  
ning of each regular issue of the PCT Gazette.

(54) Title: OPTICAL BYPASS METHOD AND ARCHITECTURE



(57) Abstract: The invention pertains to optical fiber transmission networks, and is particularly relevant to transmission of high vol-  
ume of data and voice traffic among different locations. In particular, the improvement teaches improvements to an optical transport  
system to allow for efficient and flexible network evolution.

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## **OPTICAL BYPASS METHOD AND ARCHITECTURE**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to Provisional Application Serial Number, 60/386,084  
5 entitled "Optical Bypass Method and Architecture", by Young, filed June 4, 2002.

### **FIELD OF THE INVENTION**

The present invention relates, in general, to the field of optical communications, and  
in particular to optical fiber transmission networks. The invention is particularly relevant to  
transmission of high volume of data and voice traffic among different locations. In  
10 particular, the invention teaches improvements to an optical transport system to allow for  
efficient and flexible network evolution. The invention teaches a method and architecture for  
bypassing a terminal site without affecting existing traffic.

### **BACKGROUND OF THE INVENTION**

A goal of many modern long haul optical transport systems is to provide for the  
15 efficient transmission of large volumes of voice traffic and data traffic over trans-continental  
distances at low costs. Various methods of achieving these goals include time division  
multiplexing (TDM) and wavelength division multiplexing (WDM). In time division  
multiplexed systems, data streams comprised of short pulses of light are interleaved in the  
time domain to achieve high spectral efficiency, high data rate transport. In wavelength  
20 division multiplexed systems, data streams comprised of short pulses of light of different  
carrier frequencies, or equivalently wavelength, are co-propagate in the same fiber to achieve  
high spectral efficiency, high data rate transport.

The transmission medium of these systems is typically optical fiber. In addition there  
is a transmitter and a receiver. The transmitter typically includes a semiconductor diode  
25 laser, and supporting electronics. The laser is often a DFB laser stabilized to a specified  
frequency on the ITU frequency grid. The laser may be directly modulated with a data train  
with an advantage of low cost, and a disadvantage of low reach and capacity performance. In  
many long haul systems, the laser is externally modulated using a modulator. A single stage  
modulator is sufficient for a non-return-zero (NRZ) modulation format. A two stage  
30 modulator is typically used with the higher performance return-to-zero (RZ) modulation  
format. An example of a modulator technology is the Mach-Zehnder lithium niobate

modulator. Alternatively, an electro-absorptive modulator may be used. After binary modulation, a high bit may be transmitted as an optical signal level with more power than the optical signal level in a low bit. Often, the optical signal level in a low bit is engineered to be equal to, or approximately equal to zero. In addition to binary modulation, the data can be transmitted with multiple levels, although in current optical transport systems, a two level binary modulation scheme is predominantly employed. The receiver is located at the opposite end of the optical fiber, from the transmitter. The receiver is typically comprised of a semiconductor photodetector and accompanying electronics.

Typical long haul optical transport dense wavelength division multiplexed (DWDM) systems transmit 40 to 80 10 Gbps (gigabit per second) channels across distances of 1000 to 6000 km in a single 30 nm spectral band. In a duplex system, traffic is both transmitted and received between parties at opposite end of the link. In a DWDM system, different channels operating at distinct carrier frequencies are multiplexed using a multiplexer. Such multiplexers may be implemented using array waveguide grating (AWG) technology or thin film technology, or a variety of other technologies. After multiplexing, the optical signals are coupled into the transport fiber for transmission to the receiving end of the link. The total link distance may in today's optical transport systems be two different cities separated by continental distances, from 1000 km to 6000 km, for example. To successfully bridge these distances with sufficient optical signal power relative to noise, the signal is periodically amplified using an in line optical amplifier. Typical span distances between optical amplifiers are 50-100km. Thus, for example, 30 100 km spans would be used to transmit optical signals between points 3000 km apart. Examples of inline optical amplifiers include erbium doped fiber amplifiers (EDFAs) and semiconductor optical amplifiers (SOAs).

At the receiving end of the link, the optical channels are demultiplexed using a demultiplexer. Such demultiplexers may be implemented using array waveguide (AWG) technology or thin film technology, or a variety of other technologies. Each channel is then optically coupled to separate optical receivers.

Other common variations include the presence of post-amplifiers and pre-amplifiers just before and after the multiplexer and de-multiplexer. Often, there is also included dispersion compensation with the in line amplifiers. These dispersion compensators adjust the phase information of the optical pulses in order to compensate for the chromatic dispersion in the optical fiber while appreciating the role of optical nonlinearities in the optical fiber. Another variation that may be employed is the optical dropping and adding of

channels at cities located in between the two end cities. The invention disclosed herein, would find application in any of these variations, as well as others.

Traditionally, optical transport systems are deployed in networks in order to provide connectivity among many cities on a continental or global basis. The selection of type and quantity of equipment is done according to a traffic demand schedule, and differences in demand, or changing demand will consequently change the optimum network design. Modern networks are characterized by large capital and operational costs and must be managed efficiently to be profitable in a competitive market. From a technological standpoint the efficient buildout of a network in a changing traffic demand environment is hampered by the flexibility of current optical transport equipment. There is a need for flexible optical transport systems that support optimal network designs under different traffic loads.

#### SUMMARY OF THE INVENTION

In the present invention, improvements to an optical transport system to allow for efficient and flexible network evolution are disclosed. More specifically, the invention teaches a method and architecture for bypassing a terminal site without affecting existing traffic.

In one embodiment of the invention, an architecture for optically bypassing a terminal site is taught.

In another embodiment of the invention, a method for optically bypassing a terminal site is taught.

In another embodiment of the invention, a means of upgrading a terminal site to behave effectively like an optical add-drop (OADM) site is taught.

### BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to  
5 corresponding parts and in which:

FIG. 1 is a schematic illustration of a prior art terminal site with an inefficient implementation of pass through traffic.

FIG. 2 is a schematic illustration of a terminal site with pass through traffic managed by an optical bypass switch in accordance with the invention.

10 FIG. 3 is a schematic illustration of a terminal showing the connection location to the optical bypass switch in accordance with a preferred embodiment.

FIG. 4 is a schematic illustration of a terminal showing the connection location to the optical bypass switch in accordance with an alternate preferred embodiment.

15 FIG. 5 is a schematic illustration of a terminal showing the connection location to the optical bypass switch in accordance with an alternate preferred embodiment.

FIG. 6 is a schematic illustration of a terminal showing the connection location to the optical bypass switch in accordance with an alternate preferred embodiment.

FIG. 7 is flowchart of a method of optically bypassing a terminal site in accordance with a preferred embodiment.

20 FIG. 8 is a flowchart of a method of evaluating the need for and installing optical splitters.

### DETAILED DESCRIPTION OF THE INVENTION

While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts.

- 5 The specific embodiments described herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention.

In Fig. 1 is shown a prior art block diagram of a terminal site of an optical communications network. In Fig. 1 is shown long haul fiber pair 122, terminal 110, terminal 112 and long haul fiber pair 124. Long haul fiber pair 122 and long haul fiber pair 124 are realized by cabled optical fiber such as SMF-28 or LEAF and provide media for transmitting long haul optical signals to adjacent network elements such as terminal sites, OADM sites, or amplifier sites. Terminal 110 and terminal 112 comprise a set of line cards including transceiver cards, amplifier cards, dispersion compensation cards multiplexer-demultiplexer cards, and other functional line cards. Terminal 110 provides optical to electrical termination of optical signals from long haul fiber pair 122. Terminal 110 also provides electrical to optical generation for electrical signals sent on long haul fiber pair 122. Terminal 112 provides optical to electrical termination from long haul fiber pair 124. Terminal 112 also provides electrical to optical generation for electrical signals sent on long haul fiber pair 124.

Also shown in Fig 1 is local fiber patch cord pair 126 and local node element 114. Local node element 114 may comprise a local terminal that is part of a short haul, or metro system, or it may be a switch or router. Local fiber patch cord pair 126 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of local fiber patch cord pair 126 is 10m-10km. Local fiber patch cord pair 126 provides the transmission media for optical signals between terminal 110 and local node element 114.

Also shown in Fig. 1 are pass through fiber patch cord pair 130, pass through fiber patch cord pair 132, pass through fiber patch cord pair 134, pass through fiber patch cord pair 136, and pass through fiber patch cord pair 138. Pass through fiber patch cord pair 130 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of pass through fiber patch cord pair 130 is 10-100m. Pass through fiber patch cord pair 132 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of pass through fiber patch cord pair 132 is 10-100m. Pass through fiber patch cord pair 134 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of pass through fiber patch cord pair 134 is 10-

100m. Pass through fiber patch cord pair 136 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of pass through fiber patch cord pair 136 is 10-100m. Pass through fiber patch cord pair 138 is realized by a pair of connectorized jacketed optical fibers. A non-limiting representative length range of pass through fiber patch cord pair 138 is 10-100m. The exact number of local fiber patch cord pairs and pass through fiber patch cord pairs is merely representative and non-limiting. The relative number of local fiber patch cord pairs to pass through fiber patch cord pairs is merely representative and non-limiting. Further, the number of local fiber patch cord pairs and pass through fiber patch cord pairs will change as the traffic in the network changes, over the lifetime of the system. Initially, terminal 110 will drop and add more traffic to local node element 114, than will be patched through to terminal 112. As the network grows, however, much of the traffic will end up patched through from terminal 110 to terminal 112. Modern transport equipment can support as many as 200 channels so the cost, management and routing of patch cords becomes problematic.

The invention seeks to eliminate pass through fiber patch cords in a network traffic flexible manner with no impact on the initial cost of the system. Further, since each fiber patch cord pair is connected to a transceiver card, the cost of said card will also be reduced or eliminated due to the benefits of the invention.

In Fig 2 is shown a schematic illustration of a terminal site with pass through traffic managed by an optical bypass switch in accordance with one aspect of the invention. Shown in Fig. 2 are optical splitter 202, optical combiner 204, optical combiner 206 and optical splitter 208. In a preferred embodiment, optical splitter 202 is realized by a thin film optical decoupler. In an alternate embodiment, optical splitter 202 is realized by a fused optical fiber decoupler. In a preferred embodiment, optical combiner 204 is realized by a thin film optical coupler. In an alternate embodiment, optical combiner 204 is realized by a fused optical fiber coupler. In a preferred embodiment, optical combiner 206 is realized by a thin film optical coupler. In an alternate embodiment, optical combiner 206 is realized by a fused optical fiber coupler. In a preferred embodiment, optical splitter 208 is realized by a thin film optical decoupler. In an alternate embodiment, optical splitter 208 is realized by a fused optical fiber decoupler.

Also shown in Fig. 2 is optical bypass switch 210 and optical bypass switch 212. In a preferred embodiment, optical bypass switch 210 is realized by a dynamic spectral equalizer. In a preferred embodiment, optical bypass switch 212 is realized by a dynamic spectral equalizer. Dynamic spectral equalizers are commercially available and perform three basic

functions. Firstly, dynamic spectral equalizers spectrally decompose the DWDM wavelengths (channels) on the input fiber into physically separate paths. Secondly, dynamic spectral equalizers provide channel by channel attenuation or extinguishing on a programmable and changeable basis. Thirdly, dynamic spectral equalizers spectrally recombine the non-extinguished channels onto a single output fiber.

The signal flow path of the invention may now be understood in reference to Fig. 2. An input DWDM signal propagating in long haul fiber pair 122 towards terminal 110 is split by optical splitter 202 so that a portion of the signal continues to propagate towards terminal 110 and the remaining portion propagates into optical bypass switch 210. Within optical bypass switch 210, the DWDM signal is decomposed by a diffraction grating or other spectral decomposition device. The separated channels are subsequently attenuated. The attenuation is set so that channel powers will be compatible with those channels that will be combined from the terminal in optical combiner 206. If a particular channel is to be transmitted from terminal 112, optical bypass switch 210 extinguishes that channel's wavelength. In normal mode of operation, if a particular channel is to be received in terminal 110 optical bypass switch 210 extinguishes that channel's wavelength. In broadcast mode of operation, if a particular channel is to be received in terminal 110 optical bypass switch 210 does not extinguish that channel's wavelength, however in this mode, terminal 112 may not transmit at this wavelength. The remaining channels are then recombined in optical bypass switch 210 and output optical bypass switch 210. The output signal is combined with the transmitted signals from terminal 112 in optical combiner 206.

The reverse signal flow is similar, and will now be disclosed explicitly. An input DWDM signal propagating in long haul fiber pair 124 towards terminal 112 is split by optical splitter 208 so that a portion of the signal continues to propagate towards terminal 112 and the remaining portion propagates into optical bypass switch 212. Within optical bypass switch 212, the DWDM signal is decomposed by a diffraction grating or other spectral decomposition device. The separated channels are subsequently attenuated. The attenuation is set so that channel powers will be compatible with those channels that will be combined from the terminal in optical combiner 204. If a particular channel is to be transmitted from terminal 110, optical bypass switch 212 extinguishes that channel's wavelength. In normal mode of operation, if a particular channel is to be received in terminal 112 optical bypass switch 212 extinguishes that channel's wavelength. In broadcast mode of operation, if a particular channel is to be received in terminal 112 optical bypass switch 212 does not extinguish that channel's wavelength, however in this mode, terminal 110 may not transmit at



this wavelength. The remaining channels are then recombined in optical bypass switch 212 and output optical bypass switch 212. The output signal is combined with the transmitted signals from terminal 110 in optical combiner 204.

5 In a preferred embodiment optical bypass switch 210 and optical bypass switch 212 are combined in a single bidirectional optical bypass switch commercially sold as a bidirectional dynamic spectral equalizer.

10 This architecture and method of creating optical bypass of a terminal node allows for the recovery of expensive transceivers at a terminal site, regardless of when the terminal was deployed. The optical bypass architecture may be designed and deployed for a wide variety of existing equipment in current networks. The programmability of optical bypass switch 210 and optical bypass switch 212 eliminates detailed pre-planning of a network which leads to inefficiency.

15 An important aspect of this invention is that only optical splitter 202, optical combiner 204, optical combiner 206 and optical splitter 208 need be installed with the system at initial deployment. In this manner, optical bypass switch 210 and optical bypass switch 212 can be deployed in a non-traffic effecting manner at the point in time when a sufficient amount of bypass traffic exists.

20 In Fig. 3 is shown a block diagram of certain components of terminal 110 and their arrangement relative to long haul optical fiber pair 122, optical splitter 202 and optical combiner 204. Shown in Fig. 3 are input first stage optical amplifier 310, input dispersion compensator 320, input second stage optical amplifier 312, demultiplexer 324, optical receiver 332 and optical receiver 334. Together, input first stage optical amplifier 310, input dispersion compensator 320, input second stage optical amplifier 312, demultiplexer 324, optical receiver 332 and optical receiver 334 comprise the receiving portion of terminal 110.

25 Also shown in Fig. 3 are output first stage optical amplifier 316, output dispersion compensator 322, output second stage optical amplifier 314, multiplexer 326, optical transmitter 336 and optical transmitter 338. Together, output first stage optical amplifier 316, output dispersion compensator 322, output second stage optical amplifier 314, multiplexer 326, optical transmitter 336 and optical transmitter 338 comprise the transmitting portion of terminal 110.

30 In a preferred embodiment input first stage optical amplifier 310, input second stage optical amplifier 312, output first stage optical amplifier 316 and output second stage optical amplifier 314 are realized by erbium doped fiber amplifiers (EDFAs). Input first stage optical amplifier 310, input second stage optical amplifier 312, output first stage optical amplifier 316 and output second stage optical amplifier 314 function to combat the

impairment of attenuation that the optical signals encounter in long haul fiber pair 122. In a preferred embodiment, input dispersion compensator 320 and output dispersion compensator 322 are realized by specialty dispersion compensating fiber. Input dispersion compensator 320 and output dispersion compensator 322 function to combat the impairment of dispersion that the optical signals encounter in fiber pair 122. In a preferred embodiment optical receiver 332 and optical receiver 334 are realized with semiconductor photodetectors and high speed amplifying, filtering and decision electronics, as is well known in the art. In a preferred embodiment optical transmitter 336 and optical transmitter 338 are realized with semiconductor lasers modulators, biasing and drive electronics, as is well known in the art.

5 The number of optical receivers and optical transmitters in Fig. 1 is not meant to be restrictive. Modern optical transport systems may comprise 200 optical receivers and the same number of optical transmitters. Further, as channel counts become high, additional optical amplifiers may also be deployed. It should also be noted that if optical splitter 202 and optical combiner 204 are applied to an existing terminal 110, then the internal arrangement of terminal 110 and even the presence of the components within terminal 110 may vary.

In Fig. 3, optical splitter 202 and optical combiner 204 are located outside and in close proximity to terminal 110. This location offers logistical advantages including ease of operation and installation. In alternate embodiments of this invention, alternate locations provide alternate advantages.

Referring now to Fig. 4 for an alternate preferred embodiment of the invention, optical splitter 202 and optical combiner 204 are located in alternate locations internal to terminal 110. In this embodiment of the invention, input first stage optical amplifier 310, input second stage optical amplifier 312, output first stage optical amplifier 316 and output second stage optical amplifier 314 function to combat the approximate 3dB loss associated with optical splitter 202 and optical combiner 204.

Referring now to Fig. 5 for an alternate preferred embodiment of the invention, optical splitter 202 is located internal to terminal 110 after input first stage optical amplifier 310, input second stage optical amplifier 312 to allow input first stage optical amplifier 310, input second stage optical amplifier 312 to amplify the weak input optical signal arriving at terminal 110. Optical combiner 204 is located after output second stage optical amplifier 314. This embodiment allows for the correct dispersion compensation amount to be applied to the optical signals.

Referring now to Fig. 6 for an alternate preferred embodiment of the invention, optical splitter 202 is located internal to terminal 110 after input dispersion compensator 320 and before input second stage optical amplifier 312. In this embodiment optical combiner 204 is located internal to terminal 110 after output dispersion compensator 320 and before output second stage optical amplifier 312. This embodiment allows for the correct dispersion compensation amount to be applied to the optical signals, with the smallest impact to system performance and no impact to terminal optical loss budget.

In Fig. 7 is shown a flow chart of a method for optically bypassing a terminal site is taught in accordance with the invention. In step 710, terminal 110 is installed at a terminal site in an optical network. In step 715, Optical splitter 202 and optical combiner 204 are installed in or in close proximity to terminal 110. In step 720, add channels to the network as traffic demand grows. In step 725, the decision is made whether optical bypass switch 210 and optical bypass switch 212 are justified economically. This decision is based on capital costs and discounted operational costs at the time of the decision. If the decision is negative, then no bypass switch is installed, until additional channels are added. If the decision is positive, then optical bypass switch 210 and optical bypass switch 212 are installed in step 730. In step 735, transceiver and other hardware may be recovered and redeployed elsewhere in the network.

Fig. 8 shows a flow chart of a method for evaluating the need for installing optical splitters at a terminal site in accordance with the invention for which optical bypass was not originally envisioned. In step 810, terminal 110 is installed at a terminal site on an optical network. In step 815, channels are added in the normal course to the optical network as traffic grows. At step 820 an evaluation is made of the necessity for a splitter and optical bypass system. The decision is based on capital costs and discounted operational costs at the time of the decision. If the decision is negative, then no splitter is installed, until additional channels are added. If the decision is positive, then the splitter and optical combiner are installed in step 830. In step 835, the optical bypass switch is installed. In step 840 transceiver and other hardware may be recovered and redeployed elsewhere in the network.

While this invention has been described in reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is therefore intended that the appended claims encompass any such modifications or embodiments.

**Claims:**

1. An architecture for optically bypassing a terminal site comprising:  
an optical de-coupler;  
an optical bypass switch optically coupled to an output port of said optical de-  
coupler;  
an optical coupler optically coupled to an output port of said optical bypass  
switch.
2. The architecture of claim 1 further comprising:  
a second optical decoupler,  
a second optical bypass wavelength switch optically coupled to an output port  
of said second optical de-coupler,  
a second optical coupler optically coupled to an output port of said second  
optical bypass switch.
3. The architecture of claim 1 wherein the optical decoupler is a thin film optical  
decoupler.
4. The architecture of claim 1 wherein the optical decoupler is a fused optical  
decoupler.
5. The architecture of claim 1 wherein the optical coupler is a thin film coupler.
6. The architecture of claim 1 wherein the optical coupler is a fused optical  
coupler.
7. The architecture of claim 1 wherein the bypass switch is a dynamic spectral  
equalizer.
8. A terminal for use in an optical bypass system comprising:  
an optical splitter connected to an incoming optical fiber;  
a first amplifier connected to the optical splitter;  
at least one optical receiver connected to the optical amplifier;

an optical combiner connected to an outgoing optical fiber;  
a second amplifier connected to the optical combiner;  
at least one optical transmitter connected to the second amplifier.

5           9.     The terminal of claim 8 wherein the first amplifier is a multi stage amplifier.

10           10.    The terminal of claim 9 wherein a dispersion compensation module is  
interposed in the first amplifier.

11           11.    The terminal of claim 8 wherein the second amplifier is a multi stage  
amplifier.

12           12.    The terminal of claim 11 wherein a dispersion compensator module is  
interposed in the second amplifier.

15           13.    The terminal of claim 8 wherein the optical splitter is connected to a first  
bypass switch.

20           14.    The terminal of claim 13 wherein the first bypass switch is a dynamic spectral  
equalizer.

15           15.    The terminal of claim 8 wherein the optical combiner is connected to a second  
bypass switch.

25           16.    The terminal of claim 15 wherein the second bypass switch is a dynamic  
spectral equalizer.

30           17.    A terminal for use in an optical bypass system comprising:  
a first amplifier connected an incoming optical fiber;  
an optical splitter connected to the first amplifier;  
at least one optical receiver connected to the optical splitter;  
a second amplifier connected to an outgoing optical fiber;  
an optical combiner connected to the second amplifier;  
at least one optical transmitter connected to the optical combiner.

18. The terminal of claim 17 wherein the first amplifier is a multi stage amplifier.

5 19. The terminal of claim 18 wherein a dispersion compensation module is interposed in the first amplifier.

20. The terminal of claim 17 wherein the second amplifier is a multi stage amplifier.

10 21. The terminal of claim 20 wherein a dispersion compensator module is interposed in the second amplifier.

22. The terminal of claim 17 wherein the optical splitter is connected to a first bypass switch.

15

23. The terminal of claim 22 wherein the first bypass switch is a dynamic spectral equalizer.

20 24. The terminal of claim 17 wherein the optical combiner is connected to a second bypass switch.

25. The terminal of claim 24 wherein the second bypass switch is a dynamic spectral equalizer.

25 26. A terminal for use in an optical bypass system comprising:  
a first amplifier connected to an incoming optical fiber;  
an optical splitter connected to the first amplifier;  
at least one optical receiver connected to the optical splitter;  
an optical combiner connected to an outgoing optical fiber;  
30 a second amplifier connected to the optical combiner;  
at least one optical transmitter connected to the second amplifier.

27. The terminal of claim 26 wherein the first amplifier is a multi stage amplifier.

28. The terminal of claim 27 wherein a dispersion compensation module is interposed in the first amplifier.

29. The terminal of claim 26 wherein the second amplifier is a multi stage  
5 amplifier.

30. The terminal of claim 29 wherein a dispersion compensator module is interposed in the second amplifier.

10 31. The terminal of claim 26 wherein the optical splitter is connected to a first bypass switch.

32. The terminal of claim 31 wherein the first bypass switch is a dynamic spectral  
15 equalizer.

33. A terminal for use in an optical bypass system comprising:  
an incoming multi stage amplifier having at least an incoming first stage and  
an incoming second stage connected to an incoming optical fiber;  
a first dispersion compensation module connected to the incoming first stage;  
20 an optical splitter connected to the first dispersion compensation module and  
to the incoming second stage;  
at least one optical receiver connected to the incoming second stage;  
an outgoing multi stage amplifier having at least an outgoing first stage and an  
outgoing second stage connected to an outgoing optical fiber;  
25 an optical combiner connected to the outgoing second stage;  
a dispersion compensator module connected to the optical combiner;  
the outgoing first stage connected to the dispersion combiner;  
at least one optical transmitter connected to the outgoing first stage.

30 34. The terminal of claim 33 wherein the optical splitter is connected to a first bypass switch.

35. The terminal of claim 34 wherein the first bypass switch is a dynamic spectral  
equalizer.

36. A method for optically bypassing a terminal site comprising the steps of:  
installing a terminal at an optical site in an optical network;  
installing an optical splitter and an optical combiner in conjunction with the  
terminal;  
5 adding one or more channels to the optical network;  
deploying one or more optical bypass switches if economically justified;  
recovering redundant hardware in the optical network.
37. A method for adding splitters and combiners at a terminal site comprising the  
10 steps of:  
installing a terminal at an optical site an optical network;  
adding one or more channels to the optical network;  
determining if the splitter and combiner are economically justified;  
if adding the splitter and combiner are justified then taking traffic out of  
15 surface, installing the splitters and combiners, installing an optical bypass switch and  
recovering hardware in the optical network; and  
if adding the splitter and combiner are not justified, continuing to add one or  
more channels to the optical network.



Figure 1: Prior Art

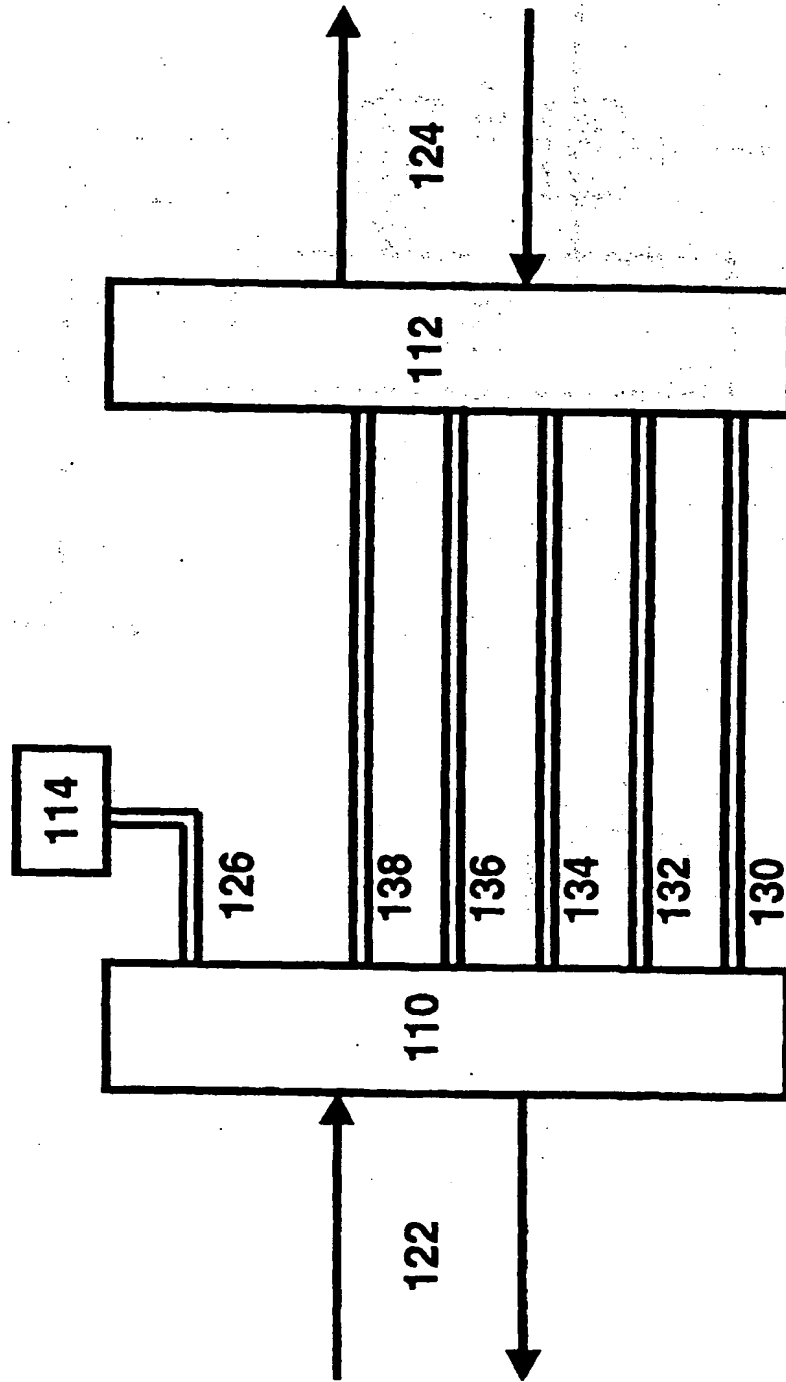


Figure 2:

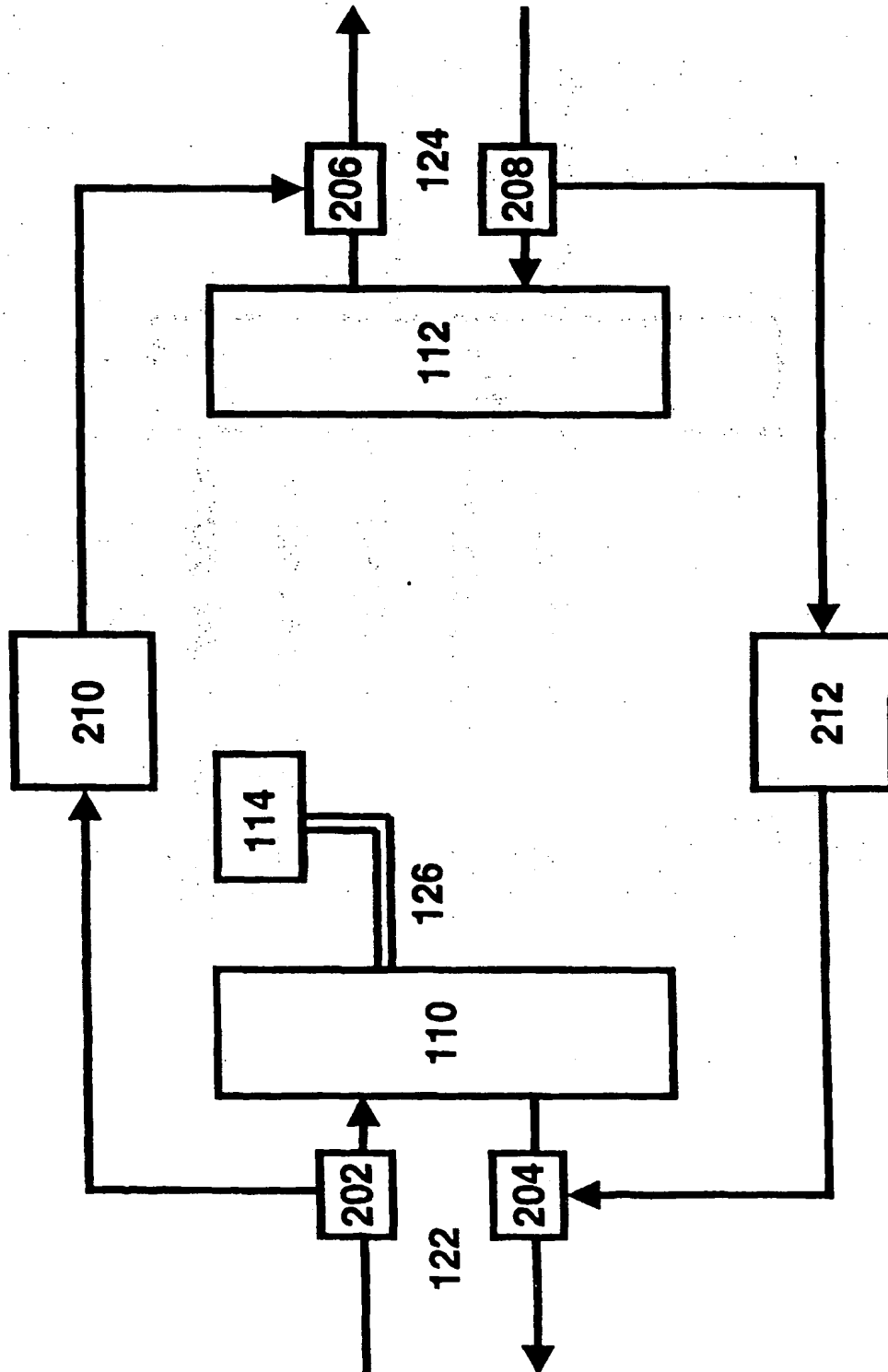


Figure 3

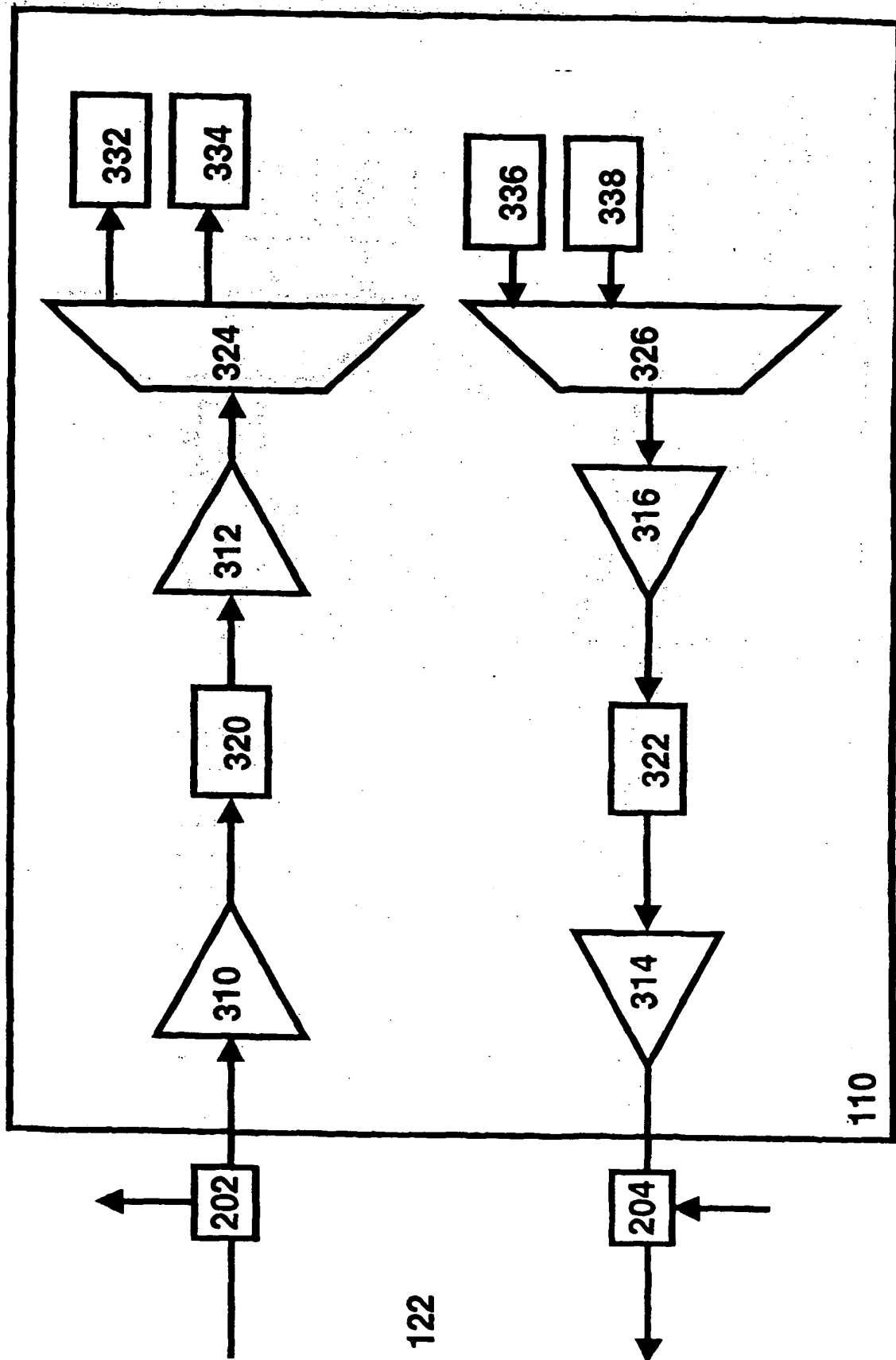


Figure 4

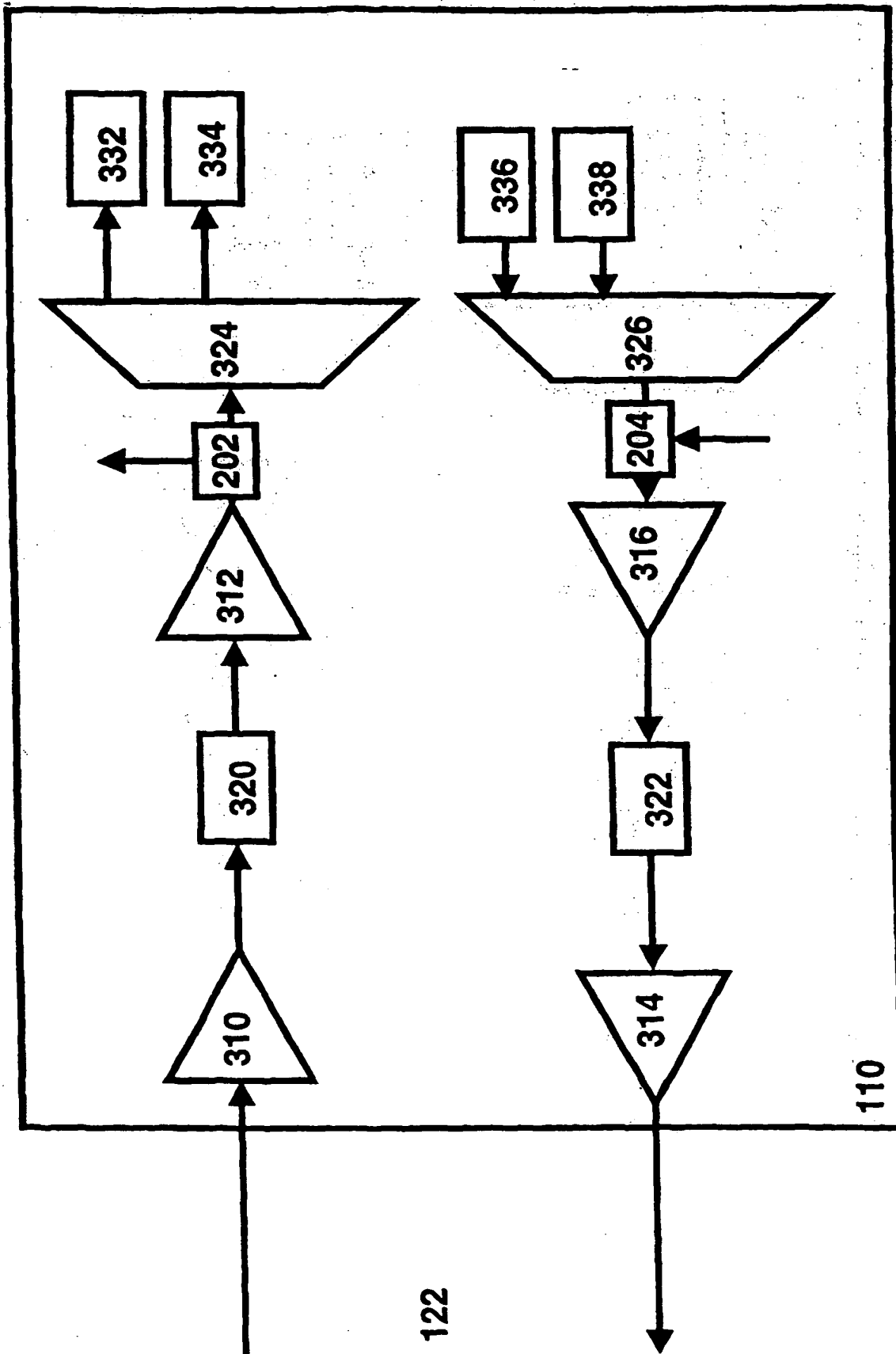


Figure 5

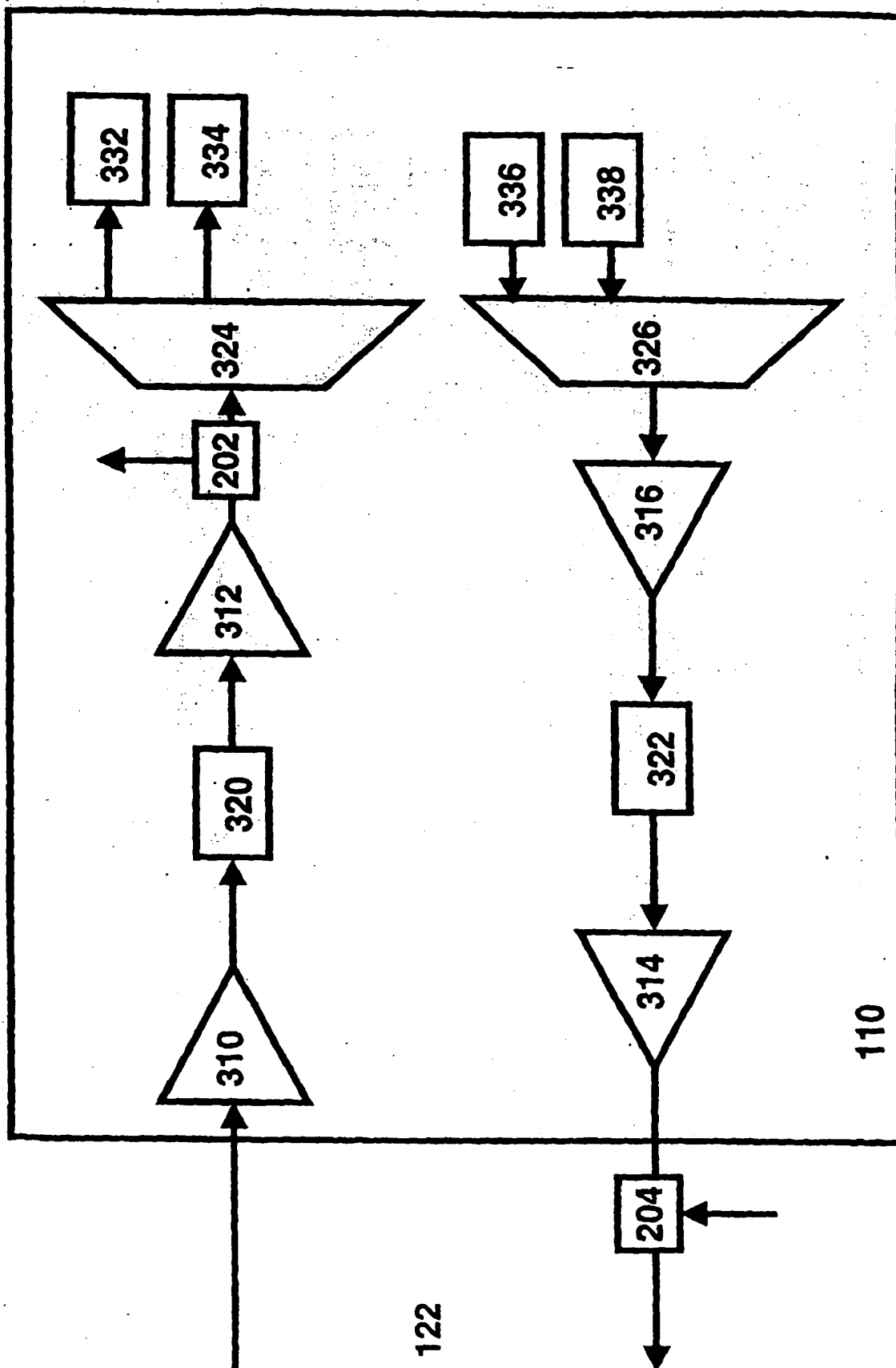


Figure 6

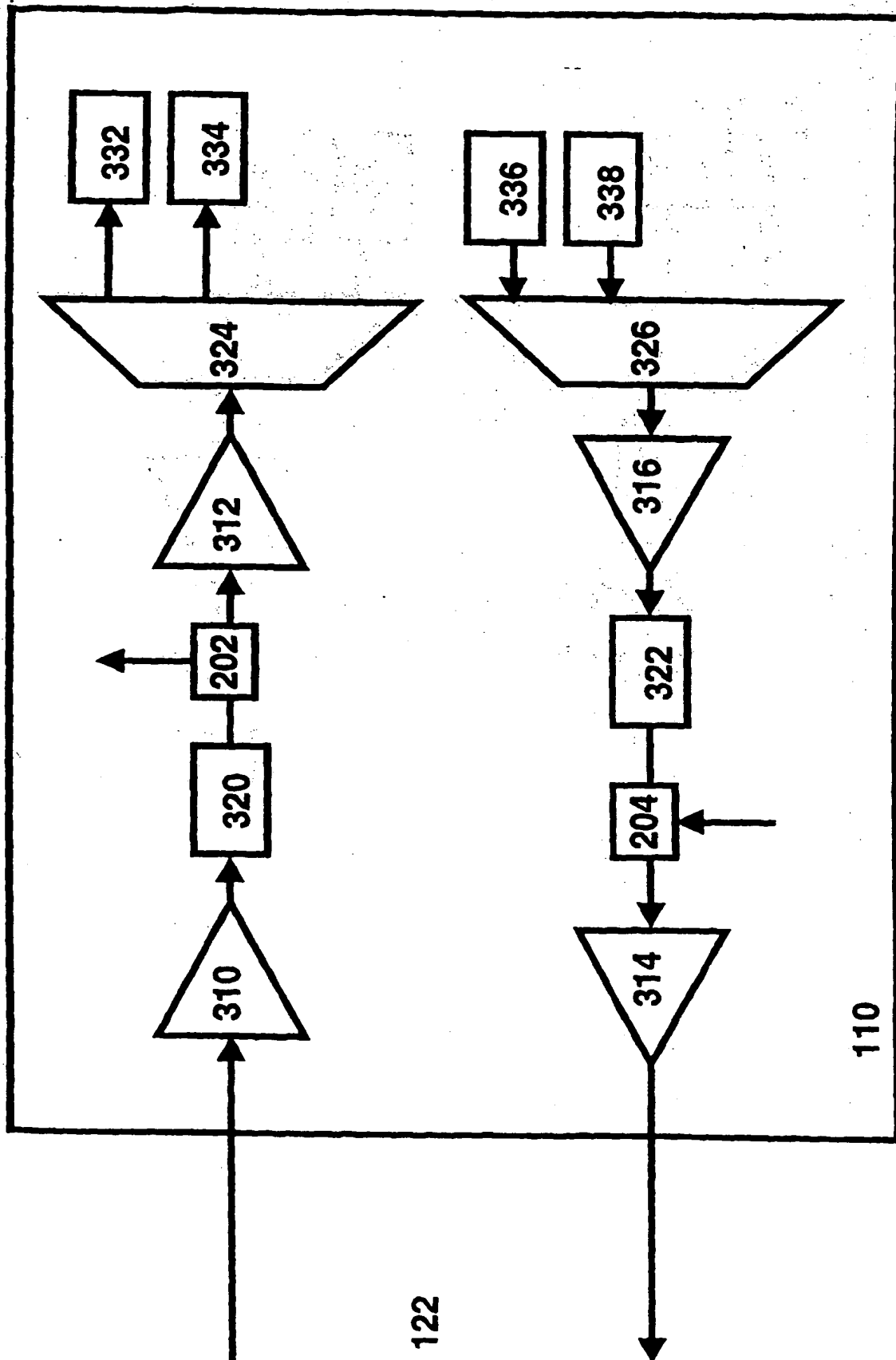


Figure 7

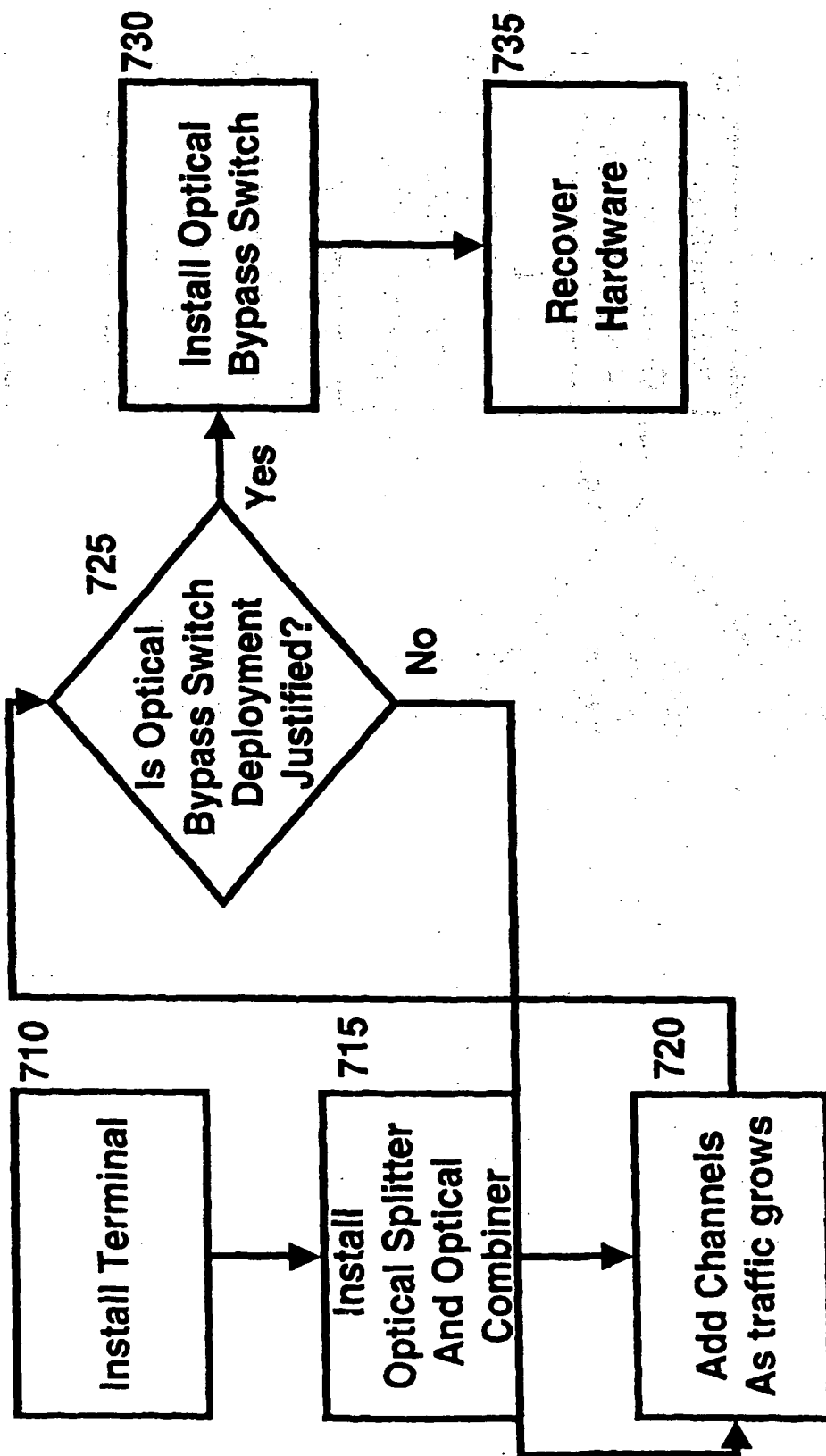
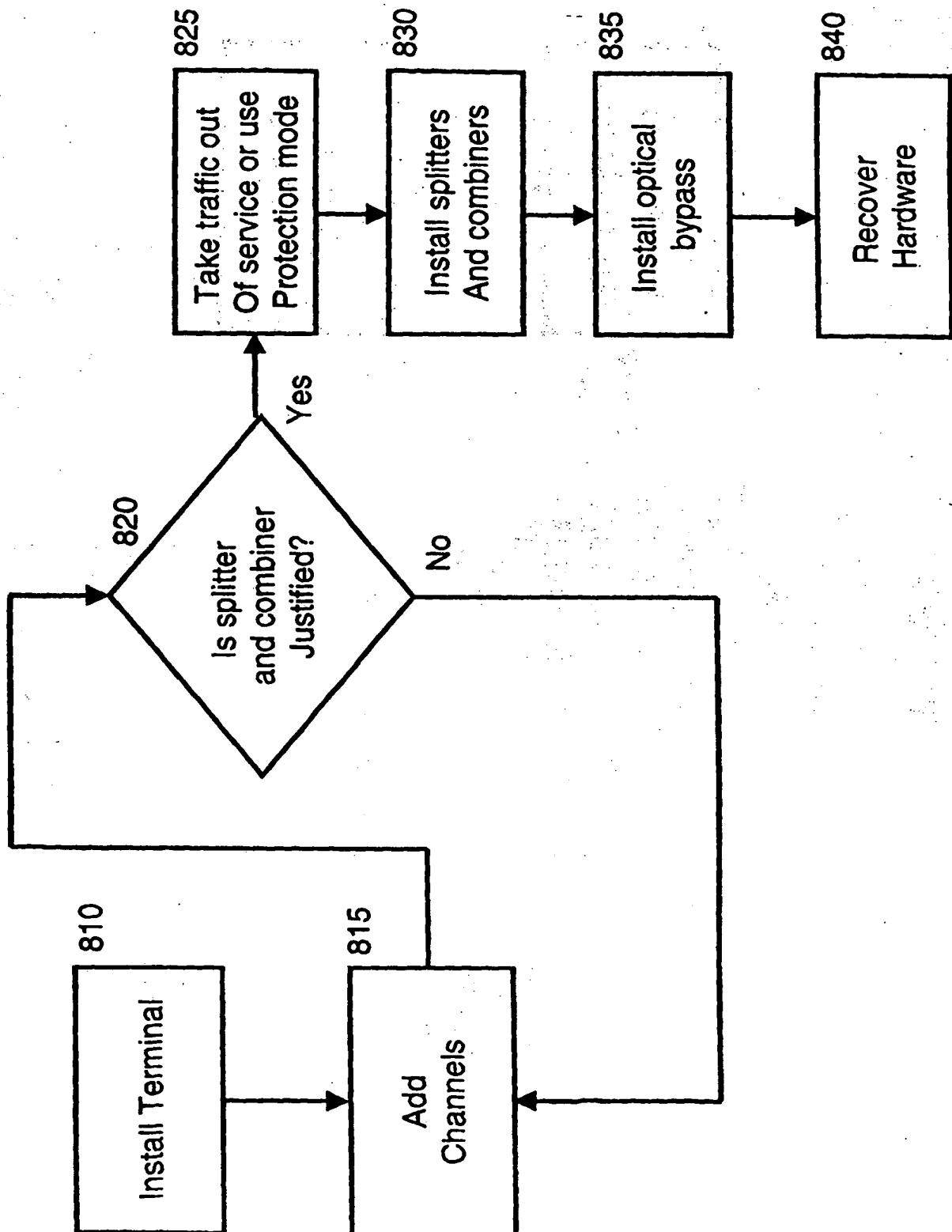


Figure 8





(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
11 December 2003 (11.12.2003)

PCT

(10) International Publication Number  
**WO 2003/102634 A3**

(51) International Patent Classification<sup>7</sup>: **H04J 14/00**, 14/02

(21) International Application Number:  
PCT/US2003/017846

(22) International Filing Date: 4 June 2003 (04.06.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
60/386,084 4 June 2002 (04.06.2002) US

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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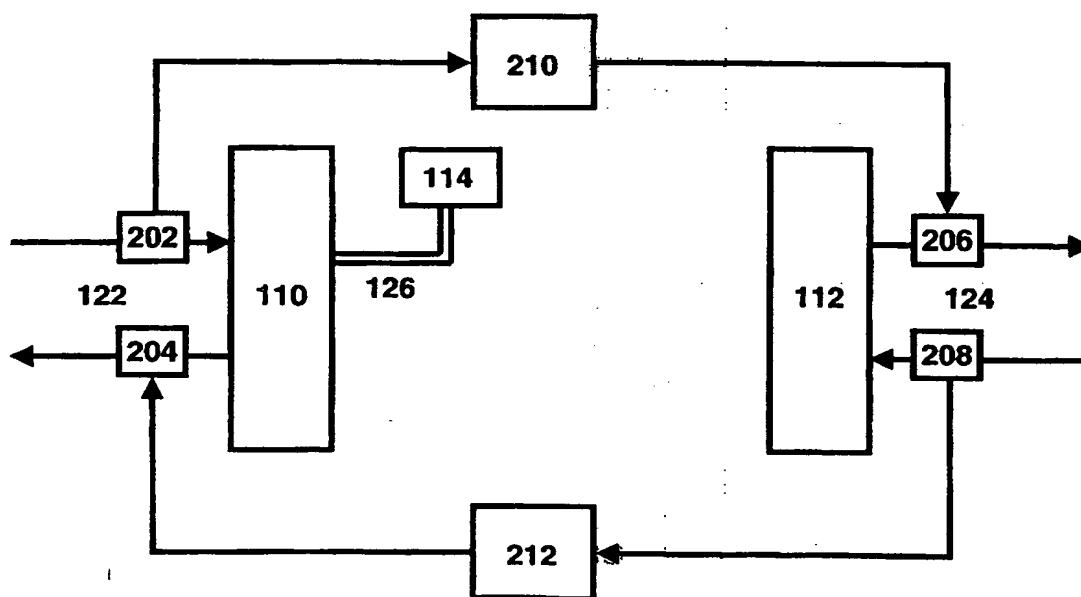
**Published:**

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(88) Date of publication of the international search report:  
24 February 2005

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: OPTICAL BYPASS METHOD AND ARCHITECTURE



(57) Abstract: A system for bypassing a terminal site comprising a first terminal (110) and second terminal (112) where optical fiber inputs and outputs (122, 124) are coupled to the terminals via optical splitters (202, 208) and optical combiners (204, 206).

WO 2003/102634 A3

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/17846

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04J 14/00, 02  
US CL : 359/124, 118, 165; 385/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 359/124, 118, 165; 385/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,600,466 A (TSUSHIMA et al.) 04 February 1997 (04.02.1997), column 5 and Fig. 1-15.	1-37
X	US 6,160,942 A (WATANABE et al.) 12 December 2000 (12.12.2000), Fig. 2 and 14-21.	33
A		1-32, 34-37

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search

03 June 2004 (03.06.2004)

Date of mailing of the international search report **20 DEC 2004**

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, Virginia 22313-1450

Facsimile No. (703) 305-3230

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